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# FLIGHT VIBRATION SURVEY OF C-133 AIRCRAFT

*PHYLLIS G. BOLDS*

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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# FOREWORD

This report was prepared in the Environmental Criteria Branch, Environmental Division, Directorate of Engineering Test, Deputy Commander/Test and Support, under Project 1309, Task 130906. The Project Engineer on this survey was Capt. Robert D. Hook of the Environmental Division. The survey covered by this report is one of a series conducted on operational aircraft by the Environmental Criteria Branch. The flights discussed in this report occurred during May and June of 1958. The information obtained from this effort was submitted as raw data to the requesting agency upon completion of the tests, and is now being presented in a formal report for the purpose of wider distribution.

## ABSTRACT

A C-133A aircraft, SN 54-138, was surveyed at Wright-Patterson Air Force Base, Ohio, to determine the vibration environment existing on the fuselage side-wall and the cargo deck under all normal flight conditions. Approximately 9,760 data points were obtained from 16 separate locations on the vehicle during three test flights. The data obtained in this survey were evaluated to determine the adequacy of vibration testing requirements of the cargo area in the C-133A aircraft. The data obtained during this survey will be used to arrive at a more realistic set of vibration test requirements concerning (1) items of cargo to be transported in aircraft such as the C-133A and (2) items of equipment which will be installed on the cargo deck or fuselage sidewalls of the C-133A.


## PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

George A. Kirsch

GEORGE A. KIRSCH
Colonel, USAF
Ass't Deputy Commander/Test and Support

REVIEW AND COORDINATION OF ASD TECHNICAL DOCUMENTARY REPORT NO. ASD-TDR-62-383

Prepared by:

Phyllis G. Bolds

PHYLLIS G. BOLDS
Project Engineer

Concurred in:

for Carl E. Reichert

LOUIS SCHAFFER
Colonel, USAF
Director of Engineering Test
Deputy Commander/Test and Support

Concurred in:

Hugh S. Lippman

HUGH S. LIPPMAN
Technical Director
Deputy Commander/Test and Support

Approved by:

George A. Kirsch

GEORGE A. KIRSCH
Colonel, USAF
Ass't Deputy Commander/Test and Support

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## SECTION I

## INTRODUCTION

One of the major problems in the design, application, testing, and use of airborne equipment is the lack of sufficient data to define the actual dynamic environment in which the vehicle equipment must operate. In most cases this lack of data has resulted in either (1) overdesigning the equipment, with its attendant excessive development costs, time, specimen size, and weight, or (2) underdesigning the equipment with a resulting lack of reliability and limited service life. To acquire the needed information, the Environmental Criteria Branch, Environmental Division, Directorate of Engineering Test, Deputy Commander/Test and Support, has implemented a comprehensive data acquisition program aimed at obtaining vibration data on all available aircraft and missiles.

This is one of a series of reports which present vibration data measured on the structure of aircraft and missiles. The primary objective of these reports is the dissemination of important dynamics data to those concerned with developing airborne accessories. These data can be used as the basis for preparing design and testing specifications, estimating environments on air vehicles in the "drawing-board" stage, establishing optimum locations and installation practices, etc. The data in this report have been interpreted only with respect to the specific vehicle of this study, i.e., C-133A, and no attempt has been made to assimilate this information with existing data on other similar vehicles or to present complete explanations of all the vibration phenomena involved. Reports will be published later to interpret the data and to draw comprehensive conclusions concerning vibration generation, propagation, structural response characteristics, and the like. However, the test instrumentation, procedures, and data reduction methods are covered in considerable detail in this report.

## SECTION II

## DISCUSSION

### A. Description of the C-133A Aircraft

The C-133A aircraft manufactured by the Douglas Aircraft Company, Inc. is a long-range, high-wing monoplane designed for use as a logistic transport. The aircraft is equipped with a fully retractable tricycle landing gear, and it is powered by four Pratt & Whitney (T34-P-7w or WA) turboprop engines. Each engine is a multistage, axial-flow, single-compressor gas turbine which produces thrust by driving a propeller at the front of the engine and discharging high-velocity gases through the nozzle at the rear. The engine is capable of developing a static maximum power (wet) of 6,500 shp. Each engine is equipped with an 18-foot Curtiss turboelectric propeller with full feathering, reverse pitch, and negative torque control features. Table I presents the principal dimensions of the C-133A aircraft.

TABLE I

C-133A GENERAL SPECIFICATION DATA

| | |
|---|---|
| Wing Span | 179 ft. 8 in. |
| Length | 157 ft. 6 in. |
| Height | 48 ft. 3 in. |
| Stabilizer Span | 60 ft. |
| Gross Weight | 275,000 lbs. |
| Engine RPM | 11,000 |
| Prop RPM | 1,020 |
| Number of Blades | 3 |
| Diameter of Propeller | 18 ft. |

## B. Test Instrumentation

The test instrumentation comprised the following: (1) twenty-four MB Manufacturing Co. Type 124 velocity pickups: (2) one Davies Laboratory, Inc. Model 501, 14-channel magnetic tape recorder, and (3) a remotely controlled pickup selector switch. The pickups on the cargo deck were mounted in groups of three and oriented to sense vibration along each of the three major axes of the aircraft. The sidewall pickups were mounted individually and oriented to measure vibration perpendicular to the sidewall of the fuselage, i.e., in the lateral direction. These pickups were attached to the aircraft cargo deck and sidewall at 16 points of interest. The locations are shown in Figure 1, Appendix A which presents a more detailed description of the instrumentation.

## C. Test Procedure

Three flights were made during this survey. Vibration records were obtained during all of the normal conditions expected in service, such as taxi, ground runup, takeoff, climb, straight and level flight (at various altitudes, airspeeds, and power settings), descent, landing, and landing roll. Magnetic tape recordings were obtained from all test pickups for each of the specified test conditions. A reel of recorded magnetic tape data consisted of approximately 90 data samples, each having, generally, a length of 75 inches and covering a period of 5 seconds. Further information concerning the test procedure is contained in Appendix A.

## D. Data Processing

The reels of recorded data were edited in the laboratory. Then, each data sample, which includes twelve channels of test data, was spliced into an endless loop. Next, each loop was placed on a Davies Model 502 tape playback system.

Then, a narrow bandwidth (10 cycles per second) analysis was conducted simultaneously on six of the twelve data channels of the loop and the analyzed data were recorded on six modified Brown strip chart recorders in the form of a continuous spectrum of frequency (cps) versus transducer voltage (rms). This procedure was repeated to analyze and record the analyzed data of the other six data channels of the loop. The analyzer used is a heterodyne type, Davies Model 510.

The data points of interest were then extracted from the strip chart recording, tabulated, and punched into IBM cards. Corresponding decks of "master cards" which contain detailed descriptive information concerning pickup location, flight test conditions, and source and order of vibration were also produced. Next, the raw data together with the formula for computing double amplitude in inches and acceleration in g units and the appropriate descriptive information on the "master cards" were fed to an ERA 1103A computer. The completed data cards were then sorted into the desired order and the data were plotted by an automatic plotter having IBM card input capabilities.

E. Presentation of Data

The plots contained in this report are: (1) summary plots for each individual pickup for all of the flight test conditions, (2) summary plots for each cluster of pickups (2 or 3) at any given test point, and (3) summary plots for structural "zones" for all of the flight test conditions. These types of data presentation have proven satisfactory for use in establishing specification requirements and in estimating vibration environments in other similar vehicles. However, in instances where more detailed analysis of the vibration characteristics is required, graphs could be prepared to show variations of many parameters affecting the vibration conditions in the vehicle. For example, graphs can be made showing variation of vibration as a function of the following parameters: (1) indicated airspeed, (2) altitude, (3) power, (4) flight condition, (5) engine and propeller orders, etc. Plots of this type can be furnished if requested. A more detailed description of data handling procedures, data analysis, and presentation methods is contained in Appendix A.

## SECTION III

## RESULTS

During the three test flights 9,762 data points were obtained. As evidenced by the graphs contained in Appendix A, the data are of the discrete frequency type. The sources of these frequencies are (1) the propeller and (2) the engine.

The frequencies produced by the propeller are apparent throughout the entire cargo deck. For the most part, the vibration produced by the propeller is a result of aerodynamic disturbances induced by the blade passage. Hence, the frequencies are multiples of the blade-passage frequency. They range from the third propeller order up to the 30th order and show distinctly every third propeller

order at approximately 50, 100, 150, 200, 250, 300, 350, 400, 450, and 500 cps. The amplitudes varied with flight conditions, location and orientation of the transducer, and the structural zone.

The vibration produced by the engine is very sparse and low in amplitude. The second engine order of approximately 355 cps was noted.

The test data indicated that the following vibration envelope would define satisfactorily the in-flight vibration characteristics of the C-133A aircraft cargo deck.

| | | |
|---|---|---|
| 5 to 10 cps | - | 0.08 in. double amplitude |
| 10 to 14 cps | - | ±0.40 g vibratory acceleration |
| 14 to 36 cps | - | 0.036 in. double amplitude |
| 36 to 500 cps | - | ±2.5 g vibratory acceleration |

Also, the data revealed that the following vibration envelope would define satisfactorily the in-flight vibration characteristics of the C-133A aircraft sidewall.

| | | |
|---|---|---|
| 5 to 10 cps | - | 0.08 in. double amplitude |
| 10 to 14 cps | - | ±0.40 g vibratory acceleration |
| 14 to 52 cps | - | 0.036 in. double amplitude |
| 52 to 500 cps | - | ±10 g vibratory acceleration |

## SECTION IV

## CONCLUSION

The resonant frequency of any vibrations isolators used should be in the 20-to 30-cps frequency band to have satisfactory operation and service life and to avoid resonant excitation.

## APPENDIX A

### Instrumentation

Twelve MB Type 124 velocity pickups were mounted in clusters of three at four separate test points on the cargo deck, and another twelve pickups were mounted individually on the fuselage sidewall. The locations are summarized in Table II and shown in Figure 1. The Type 124 velocity pickup has the following characteristics:

| | | |
|---|---|---|
| Nominal sensitivity | - | 96.4 mv(rms) per inch per sec. (rms) |
| Usable frequency range | - | 5 to 2000 cps |
| Temperature range | - | -65 to 250$^{\circ}$ F |

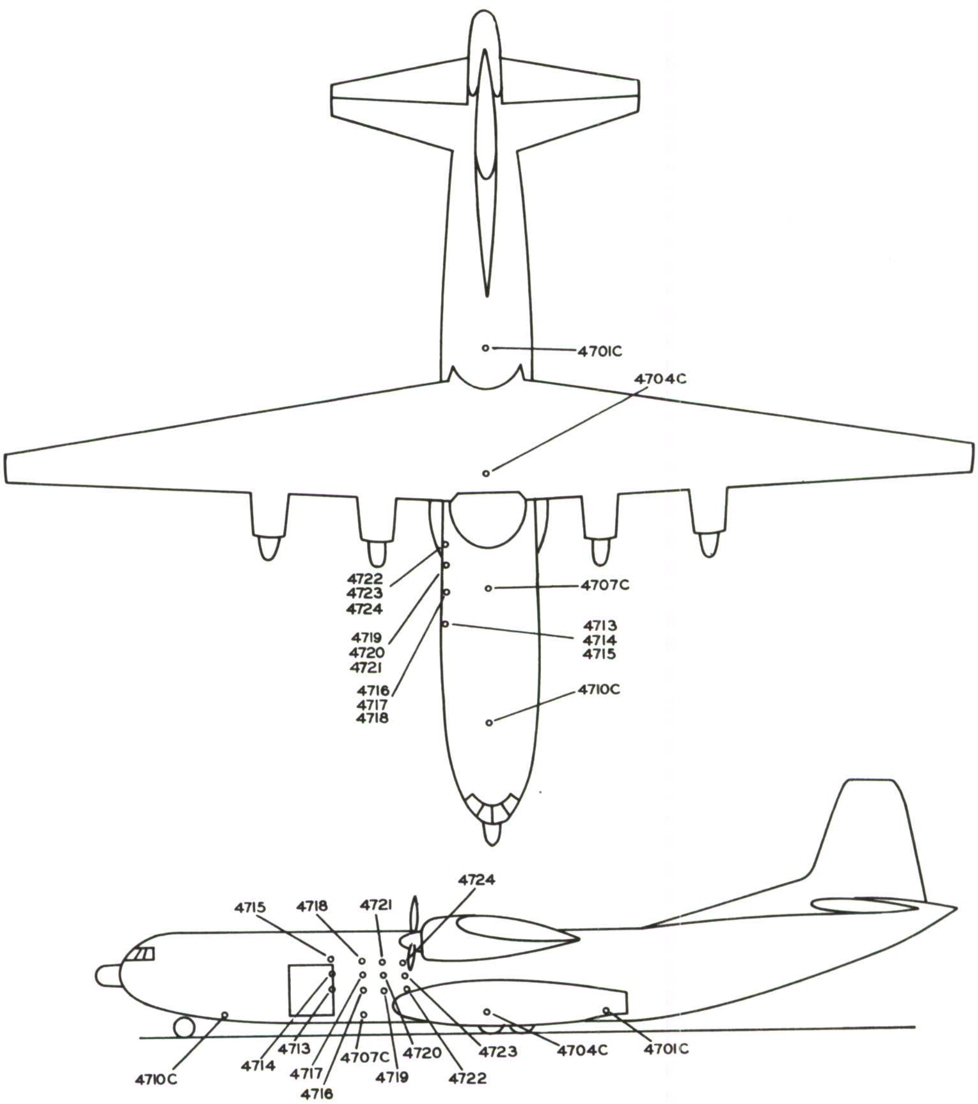


Figure 1. Schematic Presentation of Pickup Locations

TABLE II

PICKUP LOCATIONS

| PUID | Location | Direction | PUID | Location | Direction |
|---|---|---|---|---|---|
| 01<br>02<br>03 | Aft End of Cargo Deck - Sta. 1120 | Lat<br>Vert<br>F/A | 17 | Left Side of Fuselage, Forward of Prop Plane 95 in. above Deck - Sta. 580 | Lat |
| 04<br>05<br>06 | Floor of Cargo Deck - Sta. 844 | Lat<br>Vert<br>F/A | 18 | Left Side of Fuselage, Forward of Prop Plane 115 in. above Deck - Sta. 580 | Lat |
| 07<br>08<br>09 | Floor of Cargo Deck - Sta. 580 | Lat<br>Vert<br>F/A | 19 | Left Side of Fuselage, Forward of Prop Plane 57 in. above Deck - Sta. 630 | Lat |
| 10<br>11<br>12 | Forward End of Cargo Deck - Sta. 278 | Lat<br>Vert<br>F/A | 20 | Left Side of Fuselage, Forward of Prop Plane 95 in. above Deck - Sta. 630 | Lat |
| 13 | Left Side of Fuselage, Forward of Prop Plane 57 in. above Deck - Sta. 505 | Lat | 21 | Left Side of Fuselage, Forward of Prop Plane 115 in. above Deck - Sta. 630 | Lat |
| 14 | Left Side of Fuselage, Forward of Prop Plane 95 in. above Deck - Sta. 505 | Lat | 22 | Left Side of Fuselage, Forward of Prop Plane 57 in. above Deck - Sta. 680 | Lat |
| 15 | Left Side of Fuselage, Forward of Prop Plane 115 in. above Deck - Sta. 505 | Lat | 23 | Left Side of Fuselage, Forward of Prop Plane 95 in. above Deck - Sta. 680 | Lat |
| 16 | Left Side of Fuselage, Forward of Prop Plane 57 in. above Deck - Sta. 580 | Lat | 24 | Left Side of Fuselage, Forward of Prop Plane 115 in. above Deck - Sta. 680 | Lat |

A typical response curve is shown in Figure 2. The three-position mounting blocks used to attach the pickups to the vehicle structure have no resonances below 500 cps.

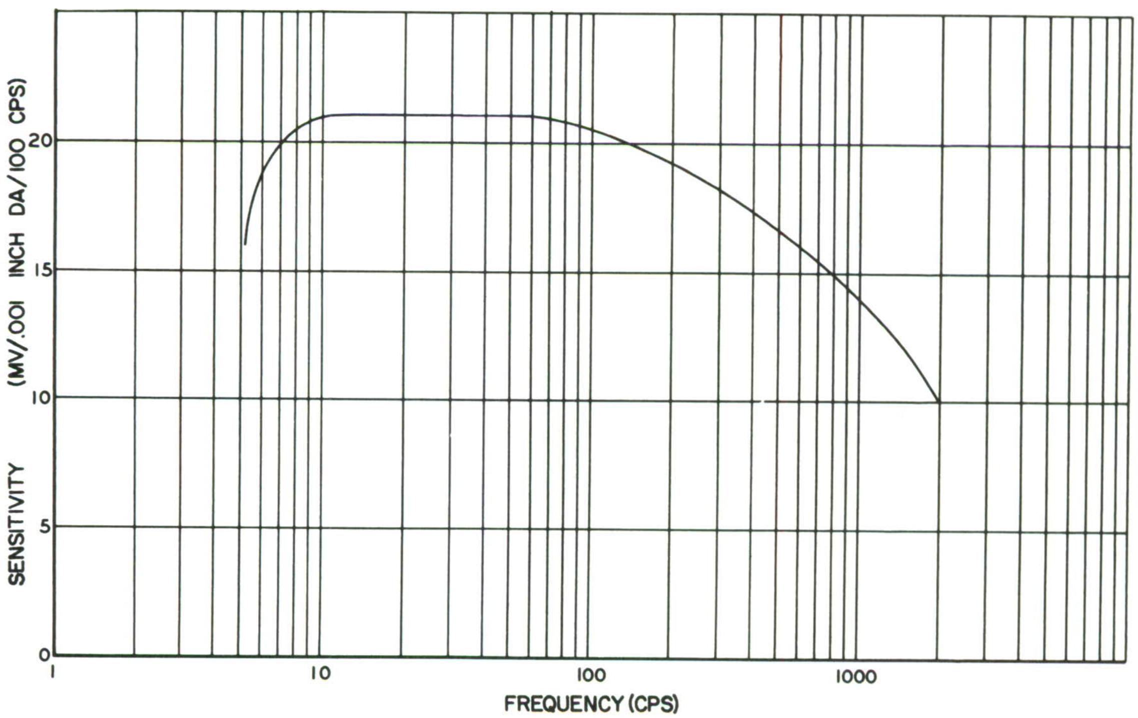


Figure 2. Frequency Response of MB Type 124 Vibration Pickup

A Davies Model 501, 14-channel magnetic tape recorder was used to record the outputs of the vibration pickups. The recorder, complete with control box and shock mount, and the pickup selector switch were installed in the nose section of the aircraft. The 26-to 28-volt DC power, required for operation of the recorder and the selector switch, was obtained from the aircraft's DC system. The recorder was preset for a recording time of five seconds. The Model 501 recorder is an FM type having the following characteristics: (1) FM carrier frequency of 10 KC, (2) intelligence frequency response of 3 to 2000 cps, (3) dynamic recording range of 45 db, (4) tape speed of 15 inches per second, (5) total recording time of approximately eight minutes, (6) weight of 55 lbs., and (7) overall dimensions, including shockmount, of 10-1/2 x 11 x 21 inches. The twelve data channels have an input impedance in excess of 100,000 ohms. The thirteenth channel has an input attenuation of approximately 45 to 1 and is designed for direct connection to the engine tachometer generator. The fourteenth channel is used to record the output from an internal, 10 KC, crystal-controlled oscillator. This channel is used during tape playback to control the playback speed by means of a servo, and it is also utilized in the electronic compensation of the tape playback and analysis system. The recorder uses 1-3/4-inch wide magnetic tape in 400-to 600-foot reels.

TABLE III

FLIGHT CONDITIONS FOR C-133A

| Flight Attitude | %RPM | IAS | Alt x $10^3$ | Torque | IHP |
|---|---|---|---|---|---|
| Taxi | 58-65 | 0 | 0 | 2.0-4.0 | 3 |
| Ground Runup | 95-97 | 0 | 0 | 25.0 | 63-64 |
| Takeoff | 100 | 50-100 | 0 | 35.0-38.0 | 93-100 |
| Climb | 96-101 | 145-200 | 1-19 | 21.5-35.0 | 57-100 |
| Straight and Level | 95-100 | 150-253 | 2-20 | 15.0-31.0 | 38-82 |
| Descent | 94-97 | 140-270 | 3-18 | 5.0-13.0 | 13-65 |
| Descent, Flaps and Gear Extended | 95 | 110-150 | 1-5 | 2.5-19.0 | 8-48 |
| Touchdown | 0 | 90 | 0 | 4.0 | 0 |
| Reverse Prop | 0 | 50 | 0 | 4.0 | 0 |
| Landing Roll | 160 | 40 | 0 | 10.0 | 27 |

## Test Procedure

Three test flights were flown during this survey. A summary of the test conditions is shown in Table III. The test plan was based on requirements of interested laboratories at ASD and on information obtained from USAF flight test pilots. Data were obtained during all of the normal operational configurations expected of the aircraft. Test conditions were also established which permitted

the evaluation of variables, such as altitude, indicated airspeed, engine thrust at constant airspeeds and altitudes, and the effects of using the speed brakes gear and other control surfaces at various airspeeds. Prior to each flight, the test pilot was thoroughly briefed on the desired flight test conditions and was given the appropriate flight test data card. As soon as the desired flight test condition was attained, the output of each of the 24 pickups was recorded in successive groups of 12 each by means of a remotely controlled selector switch. The number of data samples acquired during the three test flights totaled 155. The reels of recorded data were sent to the laboratory for analysis.

## Data Processing

The reels of tape were edited and each five-second record (data sample) was spliced into a continuous loop and properly labeled. These records were analyzed by means of a Davies Model 510 automatic analyzer, which was used in conjunction with a Davies Model 502 magnetic tape playback system. The complete playback and analysis system is shown in Figure 3.

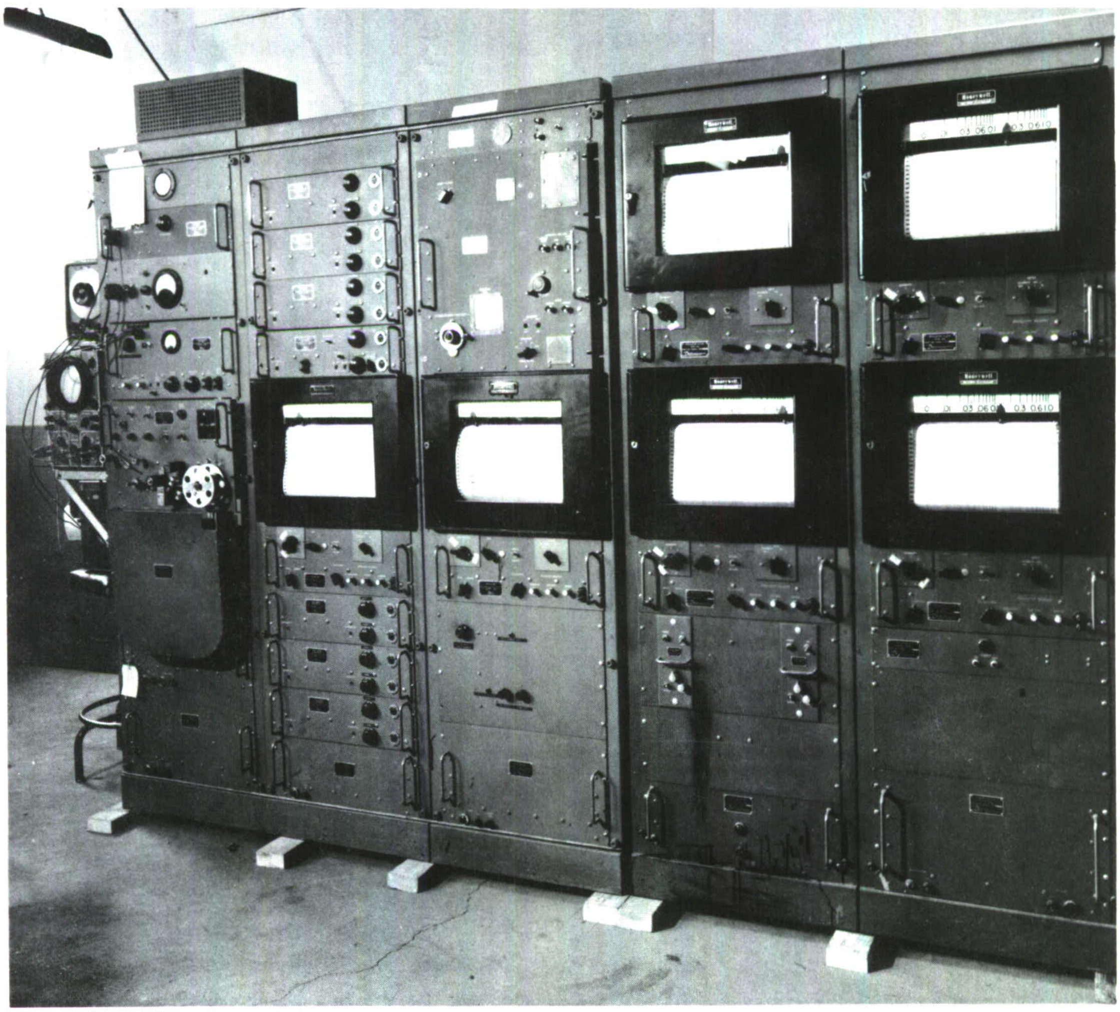

Figure 3. Automatic Tape Playback and Analysis Equipment

The Model 502 magnetic tape playback system had been modified to provide playback at either 15 or 30 inches per second. The tape playback contains a servo-control system which permits playback of the tape within very close tolerances of its originally recorded speed. During playback the output from all fourteen tracks is fed simultaneously into the fourteen FM playback discriminators. The output signal from each of the twelve data channels is a 1 to 1 reproduction of the original analog signal.

An important feature of the playback system, i.e., electronic compensation, should be discussed briefly at this point. During the data recording process, the input of the fourteenth channel is the voltage from a very stable, 10 KC crystal-controlled, reference frequency oscillator contained within the recorder. During playback, a portion of this 10 KC signal is fed into a standard FM discriminator channel. Assuming there were no wow and flutter during playback, the output voltage from this particular discriminator, i.e., the fourteenth channel, would be zero. Therefore, if any voltage is obtained from this channel during playback, it is an "error" voltage produced by wow and flutter. This "error" voltage with its phase shifted 180 degrees is fed simultaneously into the output stage of each of the twelve data channels. In this manner, the extraneous voltages due to wow and flutter are eliminated from the signal output of the data channels. Prior to playback of data, each of the data channels is adjusted for optimum cancellation (approximately 40 db). Hence, an overall dynamic range of 45 db (record through playback) can be maintained consistently. Table IV contains a summary of facts pertinent to the Davies Model 502 magnetic tape playback system and the Davies Model 510 automatic wave analyzer.

TABLE IV

SPECIFICATIONS FOR DAVIES LABORATORIES
MODEL 502 MAGNETIC TAPE PLAYBACK
AND MODEL 510 AUTOMATIC ANALYZER

| | |
|---|---|
| Frequency Range | 3 cps to 2,000 cps |
| Frequency Accuracy | 0.2 cps from 3 to 40 cps<br>0.5% from 40 to 2,000 cps |
| Input Voltage Range (2-position switch) | 1.0 volt or 10 volts rms maximum |
| Amplitude Accuracy | 5% of reading or 0.2% of full scale |
| Selectivity | Narrow Range - continuously variable from 1/2 to 8 cps<br>Broad Range - continuously variable from 8 to 45 cps |
| Scanning Speeds, Motor Drive | Speed Range 25:1 - continuously adjustable<br>Minimum Sweep Time - 15 minutes<br>Maximum Sweep Time - 6 hrs. and 15 min. |
| Recorder Speed of Response | 2 seconds for 90% full scale |
| Tape Speed | 15 or 30 inches per second |
| Loop Length | Approx. 2-1/2 ft. to at least 75 ft. |
| Tape Width | 1 and 1-3/4 inch |

The Davies Model 510 automatic analyzer is a constant-bandwidth, heterodyne analyzer complete with motor-driven, variable frequency oscillator. The system has six separate analyzers and can analyze six data channels simultaneously. Both the oscillator scanning rate and analyzer bandwidth are adjustable over the following limits: (1) scan rate 0.3 to 3.0 cps/sec. and (2) bandwidth 1 to 40 cps. The output of the six wave analyzer channels was fed into six modified Brown strip chart recorders. A continuous spectrum plot of frequency (cps) vs voltage (rms) was produced by the strip chart recorders. The chart speed is servo-controlled and can be varied from 0.08 to 13.5 inches per minute. The voltage was plotted on a logarithmic scale and the time required for full-scale deflection, i.e., zero to one volt, was approximately two seconds. A sample analysis of a 100-cps square wave is shown in Figure 4.

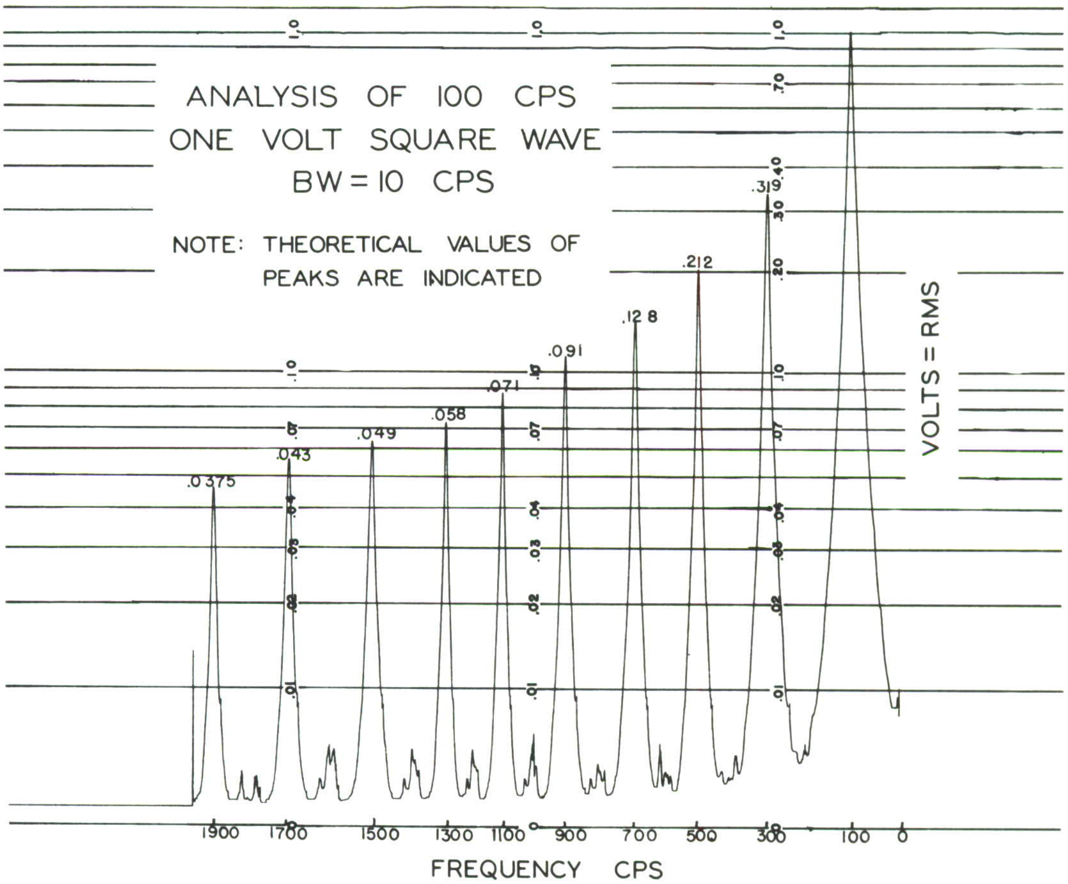


Figure 4. Analysis of 100 cps One Volt Square Wave

In selecting the bandwidth to be used in an analysis of this type, the following must be considered: (1) the frequency resolution desired, (2) the rate of scan, (3) the length of the data sample, (4) the time available for data analysis, (5) the quantity of data to be analyzed, (6) the type of data being analyzed, and (7) the type of presentation of the completed data. Based on a consideration of these variables, a bandwidth of ten cycles per second was selected for these analyses.

Following the harmonic analysis, the Brown strip chart recordings were edited and the voltage peaks of interest were marked. Each of these peaks constitutes a data point. The corresponding values of frequency and voltage for each of these peaks were tabulated, and subsequently punched into IBM cards. Each data point goes on a separate card. Then these cards were processed through the ERA 1103A computer at the rate of ninety cards per minute. Prior to processing each set or flight of data cards through the computer, a series of three sets of "master" cards was made and fed into the computer. These sets of "master" cards are:

(1) The "Flight Condition Masters"; these contain all of the necessary flight parameters, i.e., altitude, IAS, power, etc., associated with each of the data cards. This information is obtained from the flight test data card.

(2) The "Pickup Location Masters"; these contain the information required to identify each data point of each channel and record number with a particular pickup.

(3) The "Source and Order Masters"; these contain sufficient information to identify specific vibration frequencies with known orders of engine and propeller unbalance and also blade passage frequencies of the propeller or rotor blades, as the case may be.

As the data cards are processed, a new and complete "answer" card having the following information is produced: (1) the computed values of double amplitude in inches, acceleration in g's, log of frequency, log of double amplitude, and log of acceleration, (2) all of the data on the original data card, and (3) all of the appropriate data obtained from the "Master" cards. The order and limits of the information in the final analysis are shown in Table V.

After the computations were completed, all of the data cards were arranged in the desired sequence by means of an IBM sorter. Then a multi-copy IBM listing was made of all data. These listings were used in detail studies of the data and in checking the accuracy of the completed graphs.

Automatic plotters utilizing IBM card input produced the graphs of frequency in cycles per second vs. vibratory double amplitude in inches. The plotting rate ranged from 30 to 60 points per minute. The three types of graphs plotted are:

(1) Summary plots (all test conditions) for each individual vibration pickup,

(2) Summary plots for each cluster of pickups (2 or 3),

(3) Summary plots for each structural zone.

Each of the three types of graphs has all the appropriate data obtained from the three flights. No plots were made to indicate the effects of variables, such as power, altitude, IAS, etc., however, such plots can be obtained upon request.

TABLE V

SUMMARY OF INFORMATION ON IBM CARDS

| Card Column | Range | Category |
|---|---|---|
| 1 - 2 | 0 - 99 | Pickup Location |
| 3 - 4 | 1 - 31 | Day |
| 5 - 6 | 1 - 12 | Month |
| 7 - 8 | 1 - 24 | Time |
| 9 - 10 | 1 - 12 | Channel Number |
| 11 - 12 | 0 - 99 | Record Number |
| 13 - 16 | 0 - 2000 | Frequency in cps |
| 17 - 20 | 0 - .9999 | Voltage |
| 21 - 23 | 0 - 285 | Engine Speed |
| 24 - 26 | 0 - 999 | IAS in Knots |
| 27 - 28 | 0 - 60 | Altitude in 1000 feet |
| 29 - 30 | 1 - 12 | Source |
| 31 - 32 | 0 - 24 | Order |
| 33 - 34 | 1 - 63 | Flight Condition |
| 35 - 36 | N. A. | Blank |
| 37 - 41 | 0 - .9999 | Double Amplitude in Inches |
| 42 - 45 | 0 - 99.99 | Acceleration in g |
| 46 - 50 | N. A. | Log of Frequency |
| 51 - 55 | N. A. | Log of Double Amplitude |
| 56 - 60 | N. A. | Log of Acceleration |
| 61 - 62 | 0 - 45 | Aircraft I.D. Number |
| 63 - 65 | 0 - 100 | Man. Pres. -- in. Hg |
| 66 - 68 | 0 - 150 | Power Lever Angle in Degrees<br>Percent of Rated H.P.<br>Percent of Rated Thrust |
| 69 - 70 | 1 - 27 | Structural Zone |
| 71 - 80 | N. A. | Blank |

The Type 1 graphs permit a detailed study of the vibration characteristics along a single axis at a particular location in the test vehicle.

The Type 2 graphs present the overall vibration environment, measured under all test conditions, at each of the test points where 2 or 3 pickups were mounted in a cluster.

The Type 3 graphs show the overall vibration environment for a structural zone, e.g., front quarter of the fuselage. The structure of the test vehicle has been arbitrarily divided into nine major areas. Each of these major areas has been further subdivided into the following three categories: (1) vehicle structure, (2) rigidly mounted equipment, and (3) shock mounted equipment. A complete listing of these structural zones is contained in Table VI. A diagram of seven of the nine major areas is shown in Figure 5.

TABLE VI

CODE FOR STRUCTURAL ZONE OF A/C

| Code Nr. | Structural Zone |
|---|---|
| 01 | Forward Quarter of Fuselage |
| 02 | Center Half of Fuselage |
| 03 | Aft Quarter of Fuselage |
| 04 | Vert. & Horiz. Stab. Incl. Rudder & Elevators |
| 05 | Outer one-third of Wing |
| 06 | Inner two-thirds of Wing |
| 07 | Engine |
| 08 | Rigidly Mounted Equipment in Forward Quarter of Fuselage |
| 09 | Rigidly Mounted Equipment in Center Half of Fuselage |
| 10 | Rigidly Mounted Equipment in Aft Quarter of Fuselage |
| 11 | Rigidly Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators |
| 12 | Rigidly Mounted Equipment in Outer one-third of Wing |
| 13 | Rigidly Mounted Equipment in Inner two-thirds of Wing |
| 14 | Rigidly Mounted Equipment in Engine |
| 15 | Shock Mounted Equipment in Forward Quarter of Fuselage |
| 16 | Shock Mounted Equipment in Center Half of Fuselage |
| 17 | Shock Mounted Equipment in Aft Quarter of Fuselage |
| 18 | Shock Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators |
| 19 | Shock Mounted Equipment in Outer one-third of Wing |
| 20 | Shock Mounted Equipment in Inner two-thirds of Wing |
| 21 | Shock Mounted Equipment in Engine |
| 22 | Engine Accessory Section |
| 23 | Main Rotor Transmission Case |
| 24 | Rigidly Mounted on Engine Accessory Section |
| 25 | Rigidly Mounted on Main Rotor Transmission Case |
| 26 | Shock Mounted on Engine Accessory Section |
| 27 | Shock Mounted on Main Rotor Transmission Case |

All graphs are log-log (3 x 5 cycle) plots of frequency vs. vibratory double amplitude. As indicated previously, the logs of frequency, double amplitude, and acceleration were determined during the computation phase of data reduction. These

computations are necessary for the automatic plotting of frequency vs. double amplitude on a log-log scale. For the standard automatic plotters available can not accept linear input and then plot on a log scale. Therefore, by using the proper scale factors, the logarithms of the desired variables can be fed to any standard plotter to produce log-log plots of the original data. On these graphs of frequency vs. double amplitude, levels of vibratory acceleration appear as straight lines of constant slope. Reference lines having values of $\pm 0.5$, $\pm 1.0$, $\pm 5.0$, and $\pm 10.0$ g are included on all graphs. This arrangement permits simultaneous readings of double amplitude and acceleration at any given frequency.

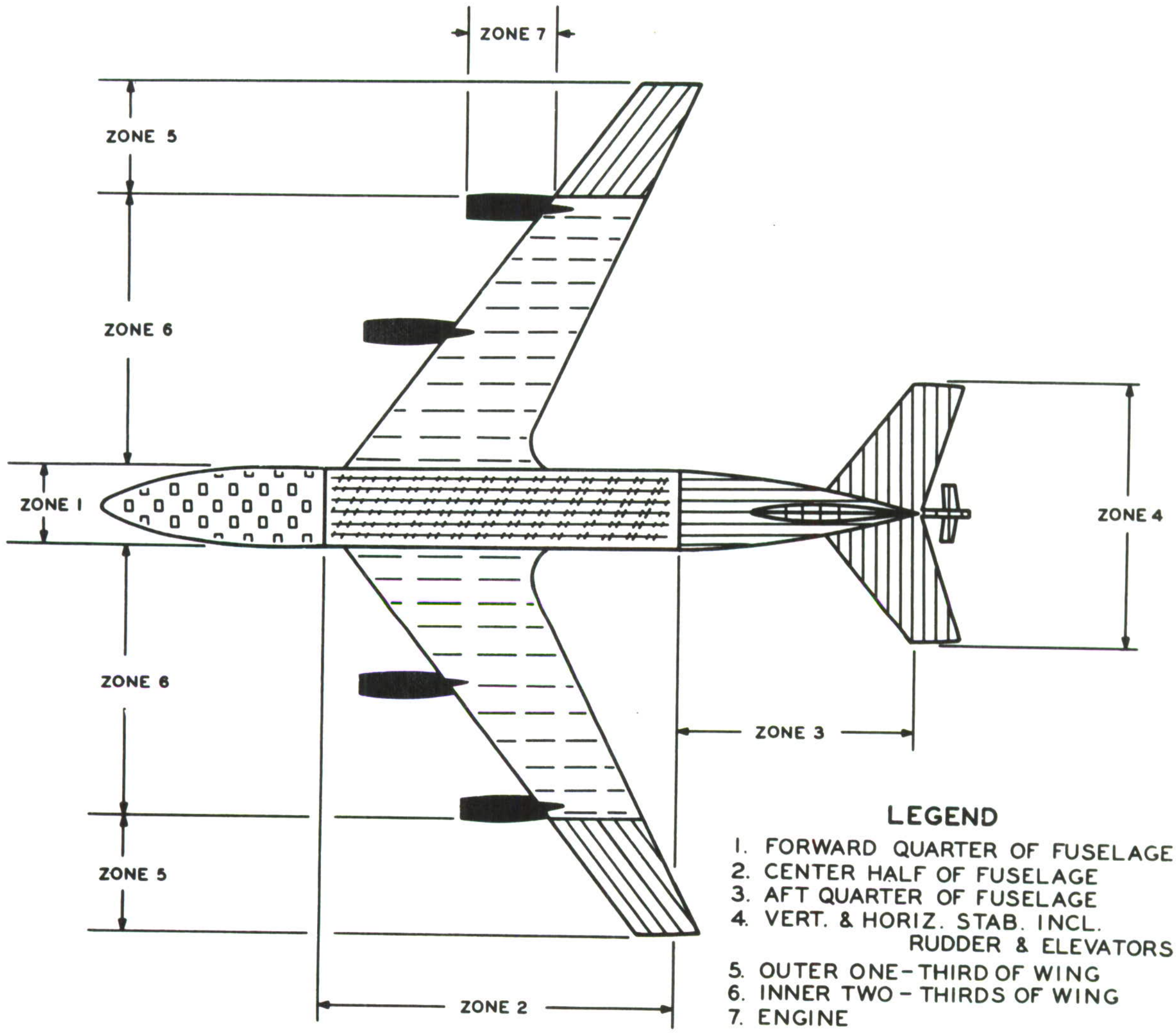


Figure 5. Aircraft Configuration Depicting Seven Structural Zones

A more detailed description of the data reduction processes used to reduce the vibration data is contained in WADC TN 59-44, ASTIA Document Nr. AD210478, dated February 1959, which is titled, "Data Reduction Techniques for Flight Vibration Measurements."

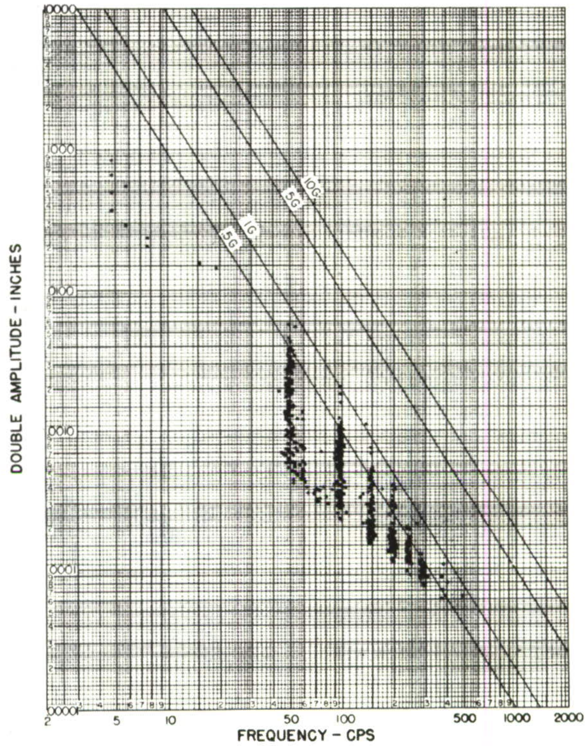


Figure 6. LOCATION: FORWARD QUARTER OF FUSELAGE

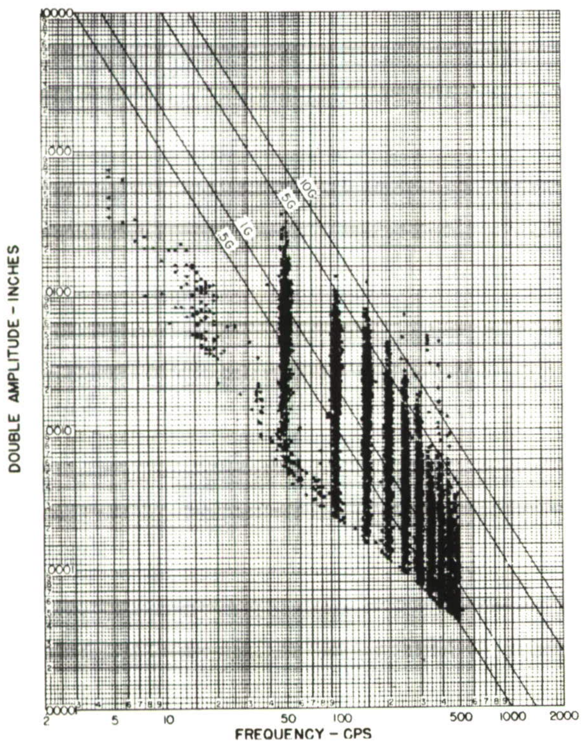


Figure 7. LOCATION: CENTER HALF OF FUSELAGE

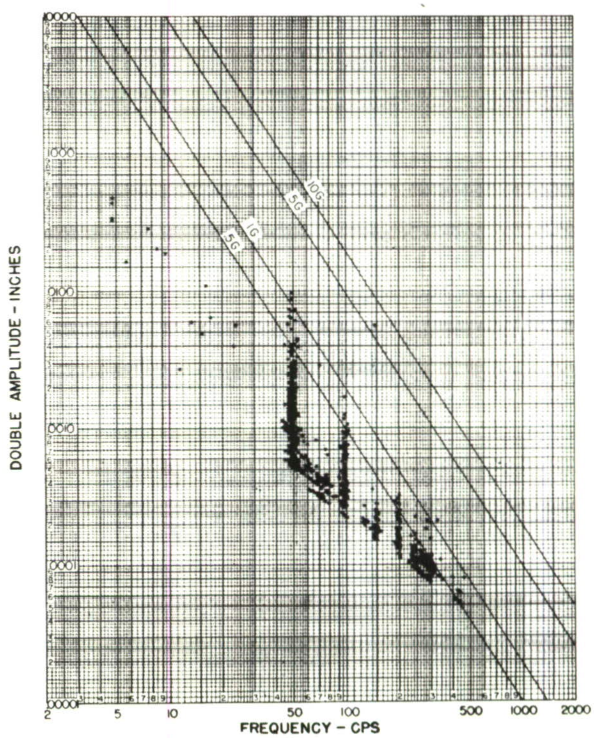


Figure 8. LOCATION: AFT QUARTER OF FUSELAGE

Figures 6 to 8. Summary Plots for Structural Zones

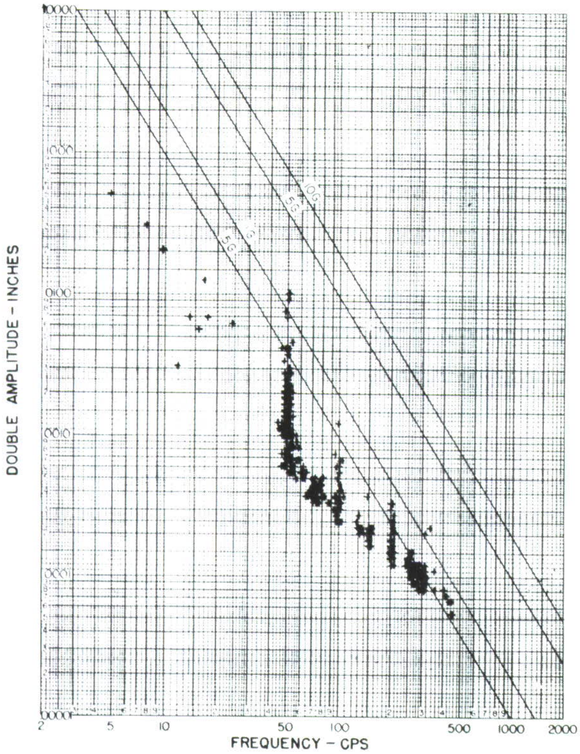


Figure 9.

DIRECTION: LAT, VERT, F/A
LOCATION: AFT END OF CARGO DECK, STA-1120

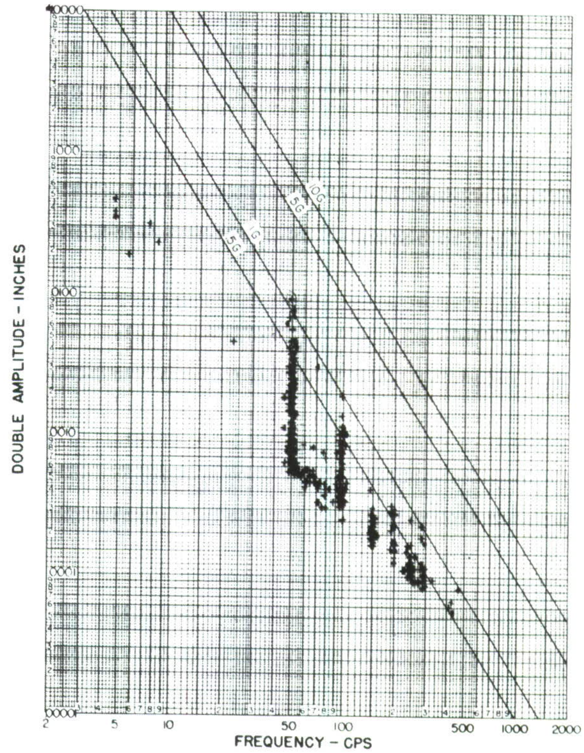


Figure 10.

DIRECTION: LAT, VERT, F/A
LOCATION: FLOOR OF CARGO DECK, STA-844

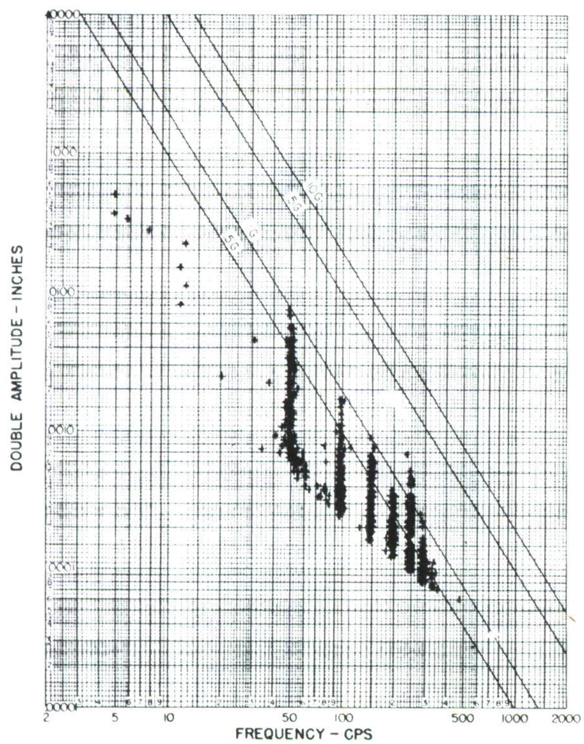


Figure 11.

DIRECTION: LAT. VERT, F/A
LOCATION: FLOOR OF CARGO DECK, STA-580

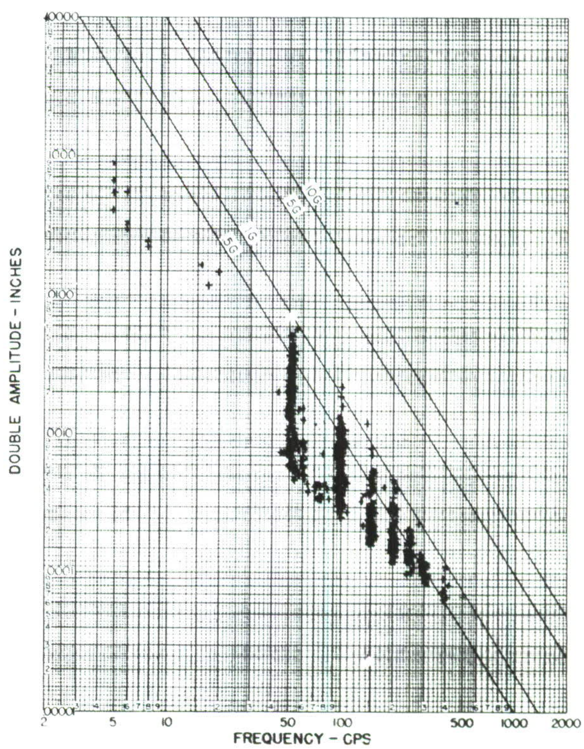


Figure 12.

DIRECTION: LAT, VERT, F/A
LOCATION: FWD. END OF CARGO DECK, STA-278

Figures 9 to 12. Summary Plots for Clusters of Two or Three Pickups

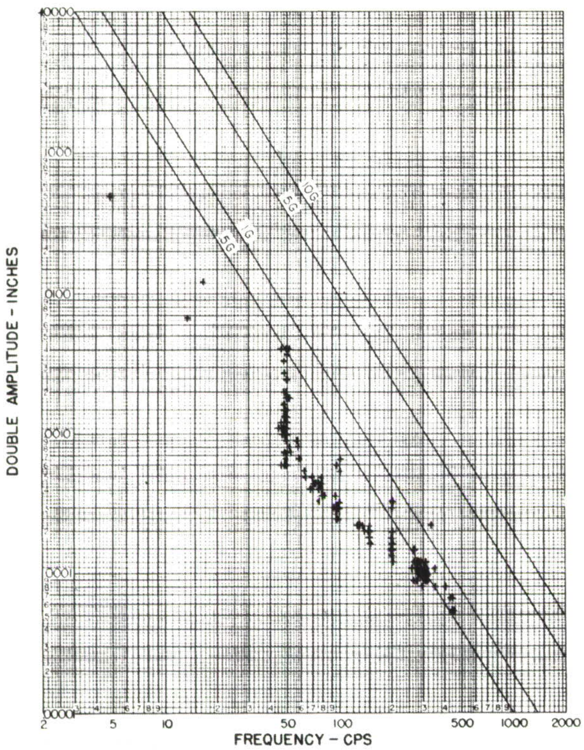


Figure 13. DIRECTION: LAT
LOCATION: AFT END OF CARGO DECK, STA-1120

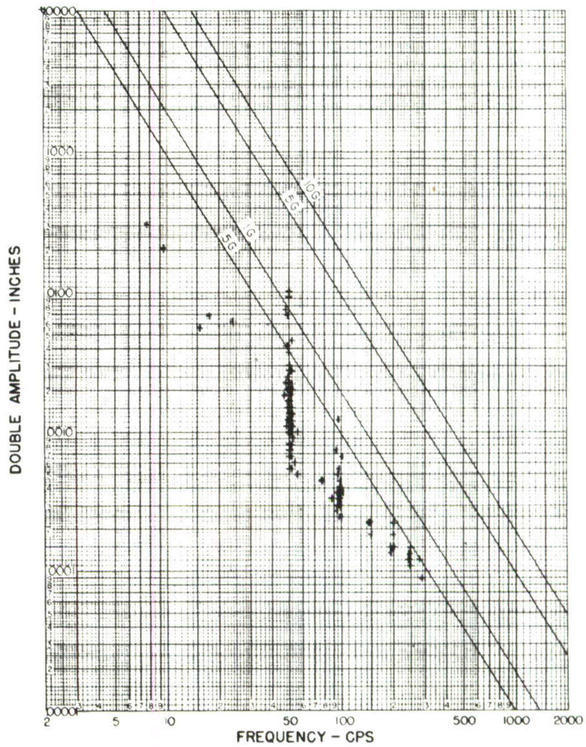


Figure 14. DIRECTION: VERT
LOCATION: AFT END OF CARGO DECK, STA-1120

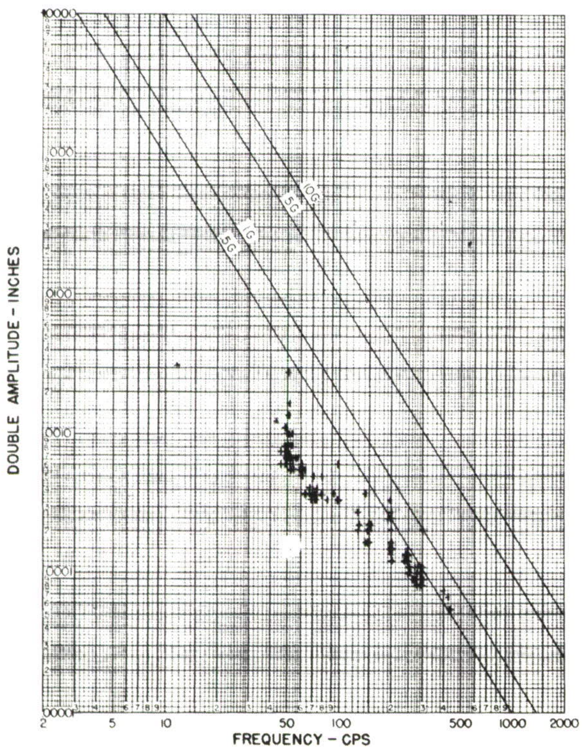


Figure 15. DIRECTION: F/A
LOCATION: AFT END OF CARGO DECK, STA-1120

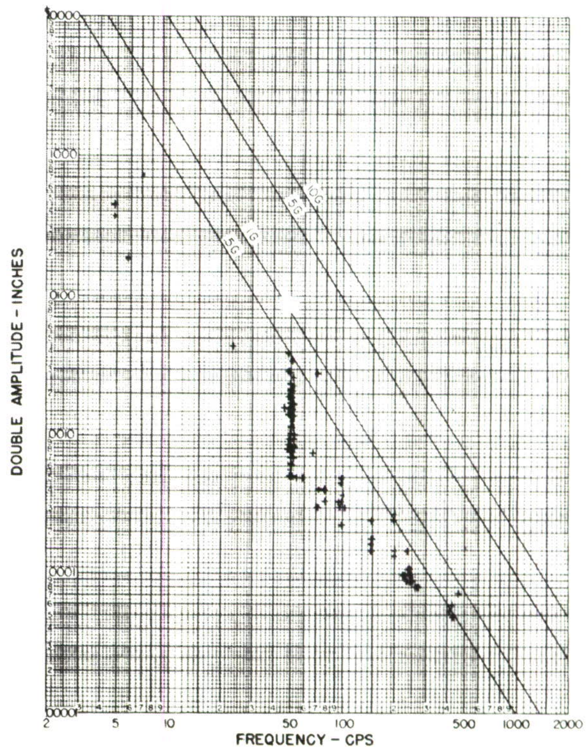


Figure 16. DIRECTION: LAT
LOCATION: FLOOR OF CARGO DECK, STA-844

Figures 13 to 16. Summary Plots for Individual Vibration Pickups

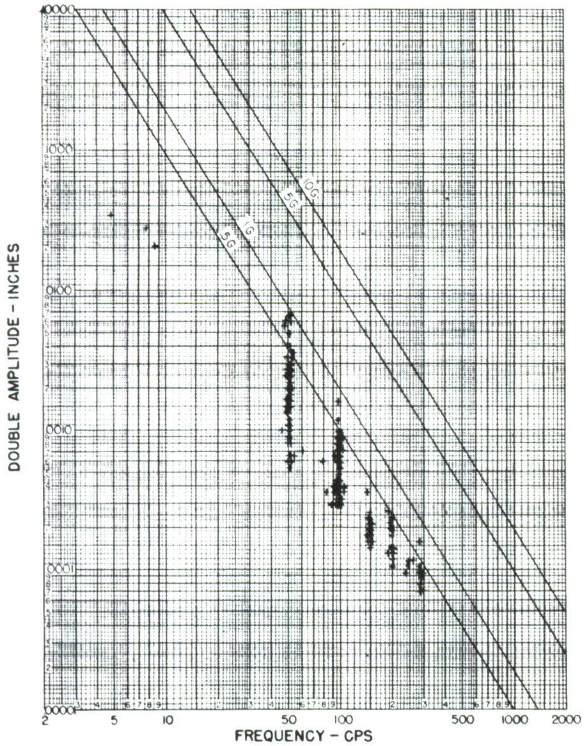


Figure 17.

DIRECTION: **VERT**
LOCATION: **FLOOR OF CARGO DECK, STA-844**

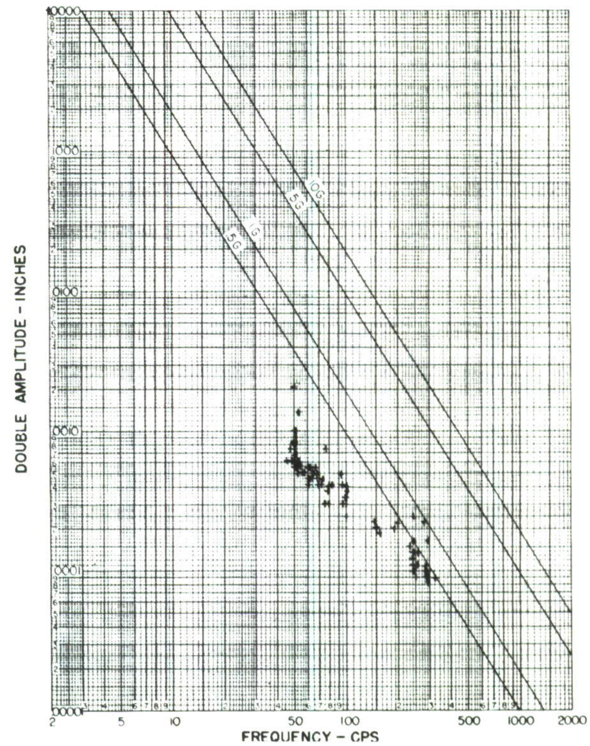


Figure 18.

DIRECTION: **F/A**
LOCATION: **FLOOR OF CARGO DECK, STA-844**

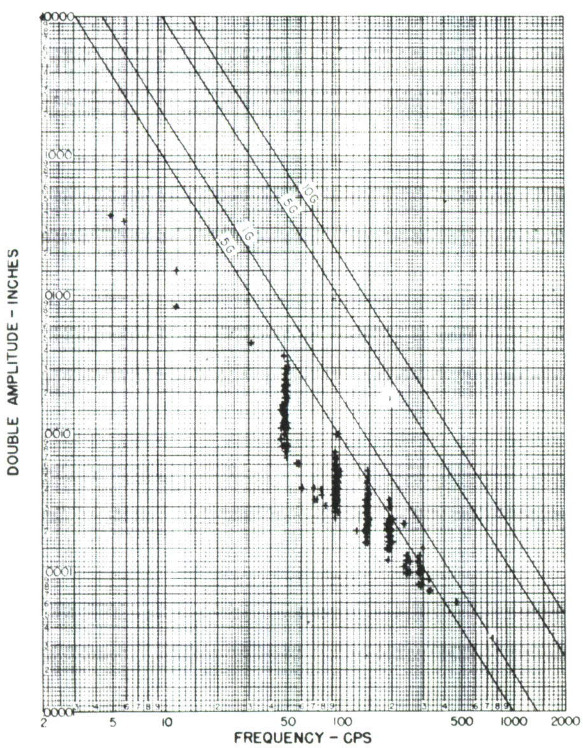


Figure 19.

DIRECTION: **LAT**
LOCATION: **FLOOR OF CARGO DECK, STA-580**

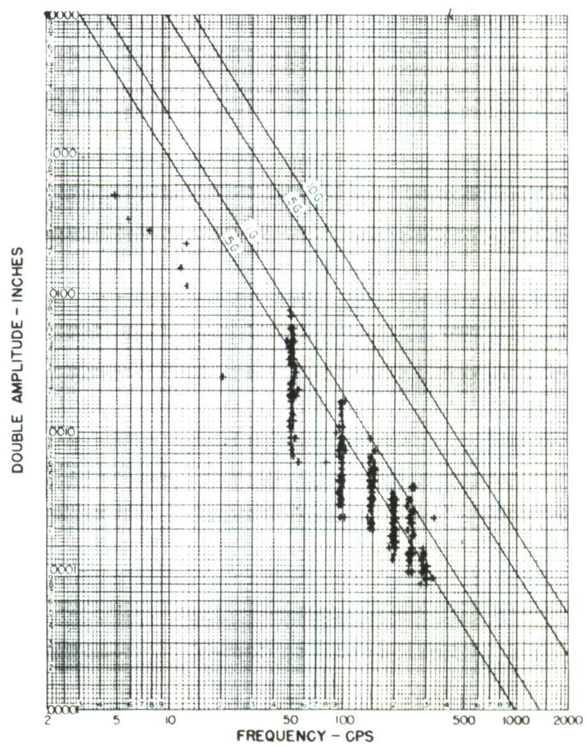


Figure 20.

DIRECTION: **VERT**
LOCATION: **FLOOR OF CARGO DECK, STA-580**

Figures 17 to 20. Summary Plots for Individual Vibration Pickups

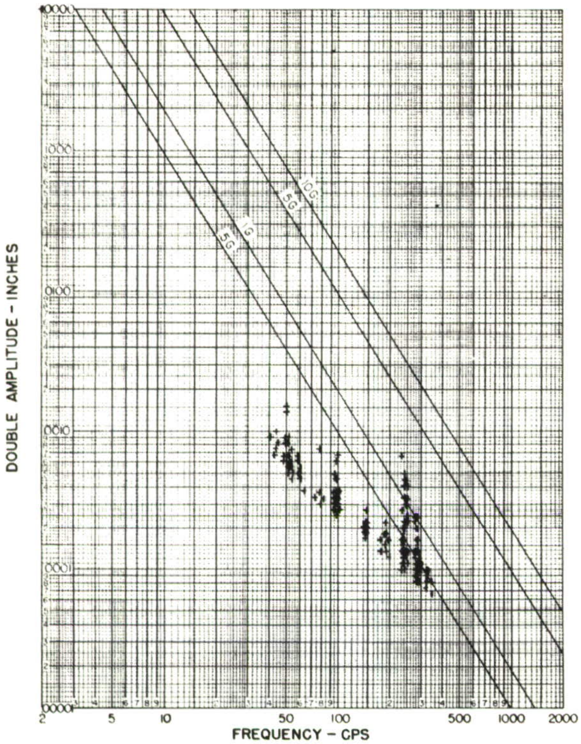


**Figure 21.** DIRECTION: **F/A**
LOCATION: **FLOOR OF CARGO DECK, STA-580**

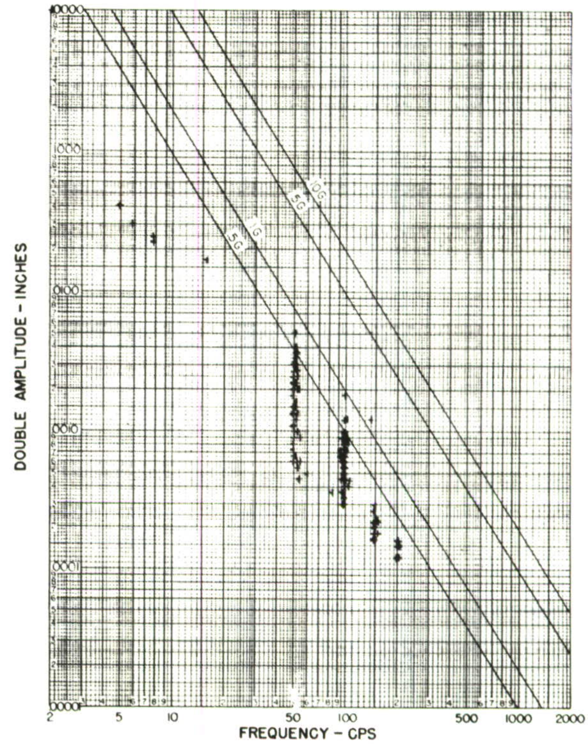


**Figure 22.** DIRECTION: **LAT**
LOCATION: **FWD. END OF CARGO DECK, STA-278**

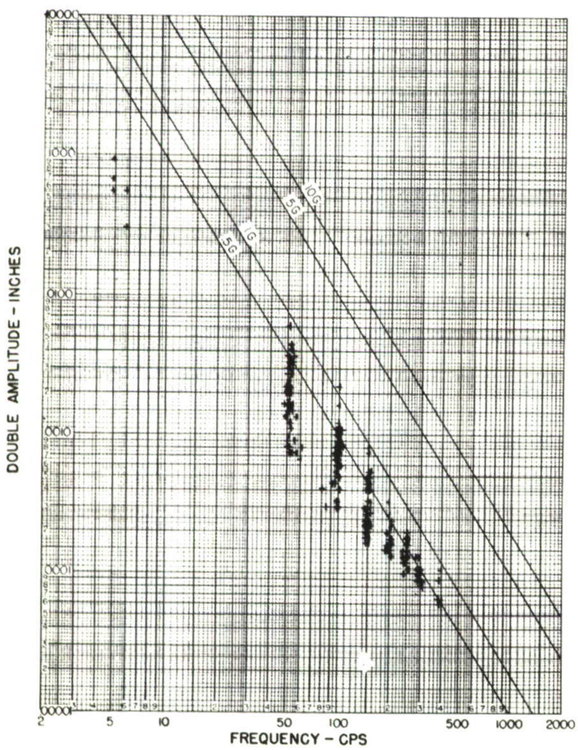


**Figure 23.** DIRECTION: **VERT**
LOCATION: **FWD. END OF CARGO DECK, STA-278**

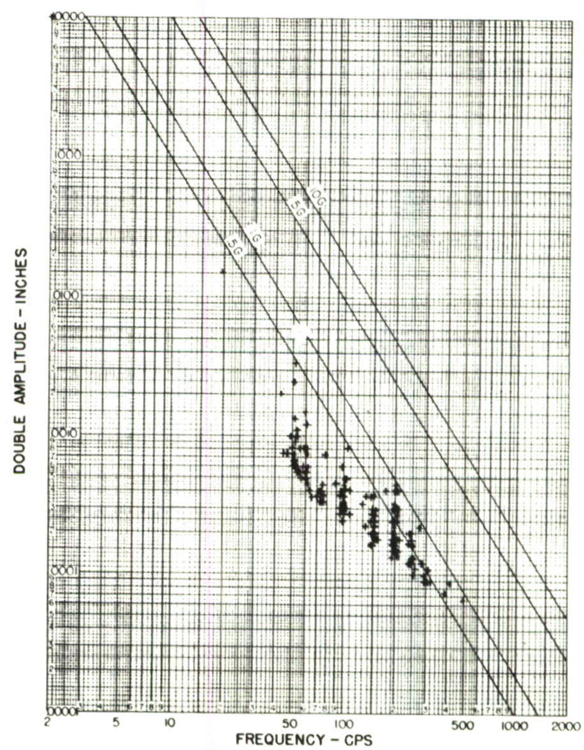


**Figure 24.** DIRECTION: **F/A**
LOCATION: **FWD. END OF CARGO DECK, STA-278**

Figures 21 to 24. Summary Plots for Individual Vibration Pickups

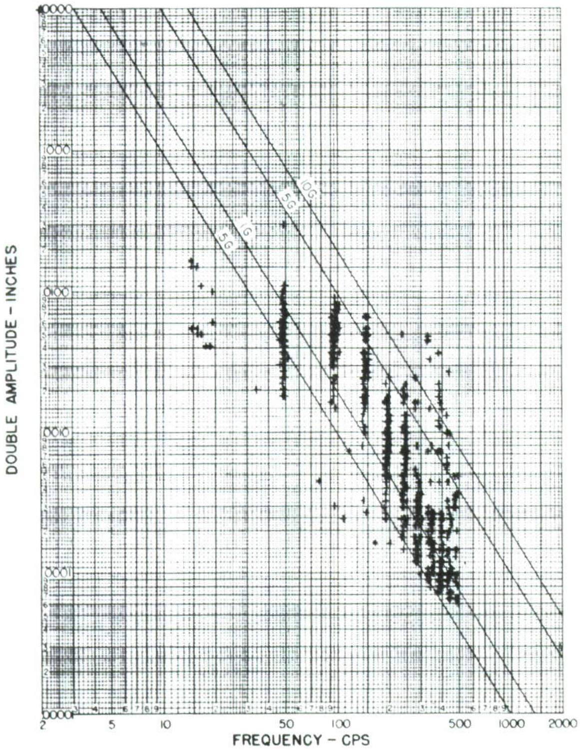


Figure 25. DIRECTION: LAT
LOCATION: LEFT SIDE FUSELAGE FWD. OF PROP PLANE 57" ABOVE DECK, STA-505

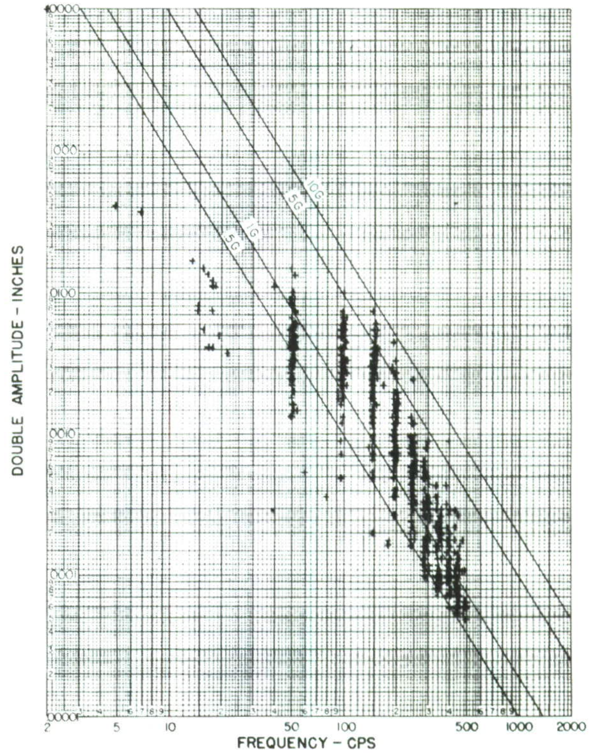


Figure 26. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE 95" ABOVE DECK, STA-505

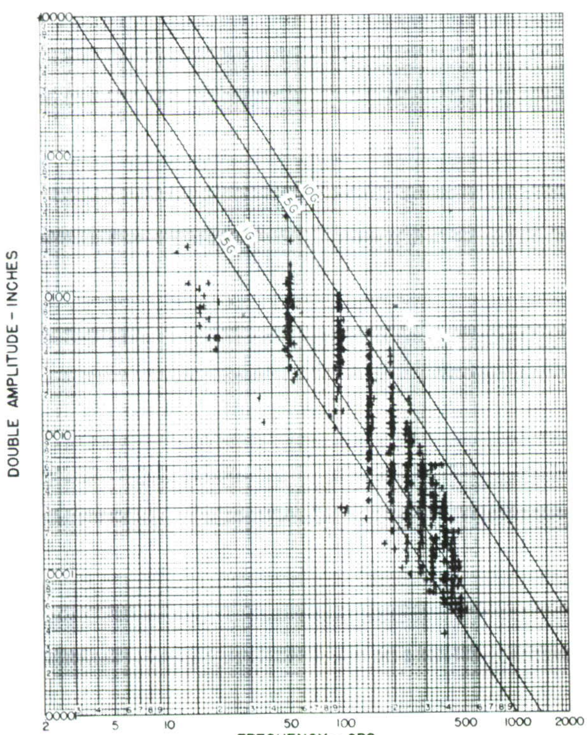


Figure 27. DIRECTION: LAT
LOCATION: LEFT SIDE FUSELAGE FWD. OF PROP PLANE 115" ABOVE DECK, STA-505

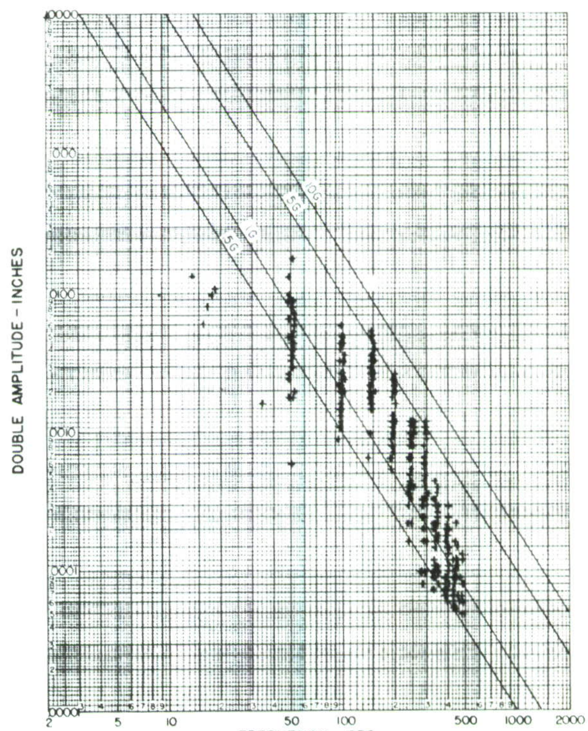


Figure 28. DIRECTION: LAT
LOCATION: LEFT SIDE FUSELAGE FWD. OF PROP PLANE 57" ABOVE DECK, STA-580

Figures 25 to 28. Summary Plots for Individual Vibration Pickups

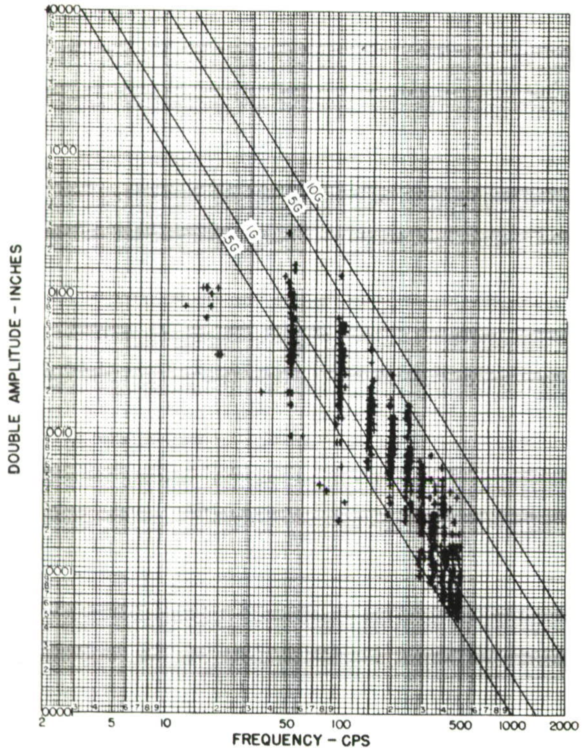


Figure 29. DIRECTION: LAT
LOCATION: LEFT SIDE FUSELAGE FWD. OF PROP PLANE 95" ABOVE DECK, STA-580

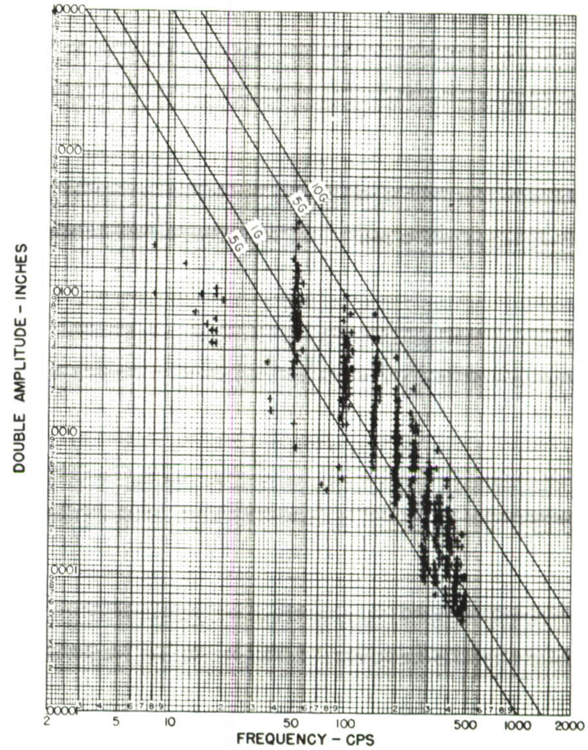


Figure 30. DIRECTION: LAT
LOCATION: LEFT SIDE FUSELAGE FWD. OF PROP PLANE 115" ABOVE DECK, STA-580

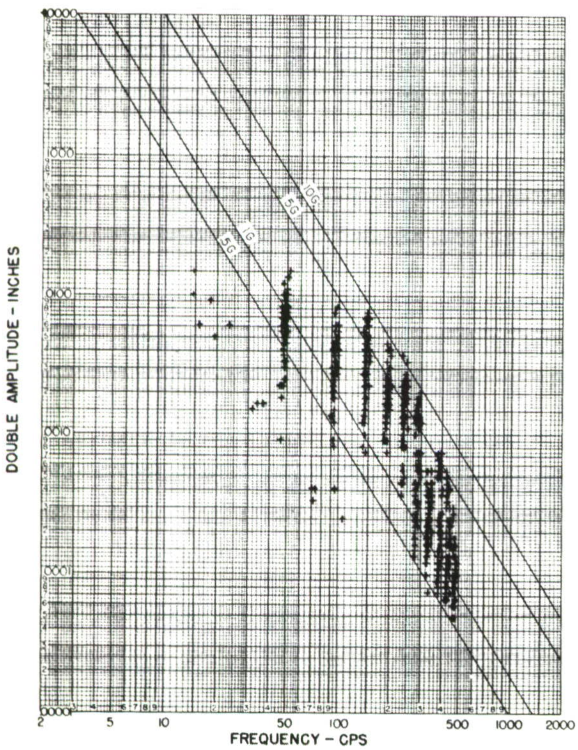


Figure 31. DIRECTION: LAT
LOCATION: SIDEWALL-LEFT SIDE FUSELAGE FWD. OF PROP PLANE 57" ABOVE DECK, STA-630

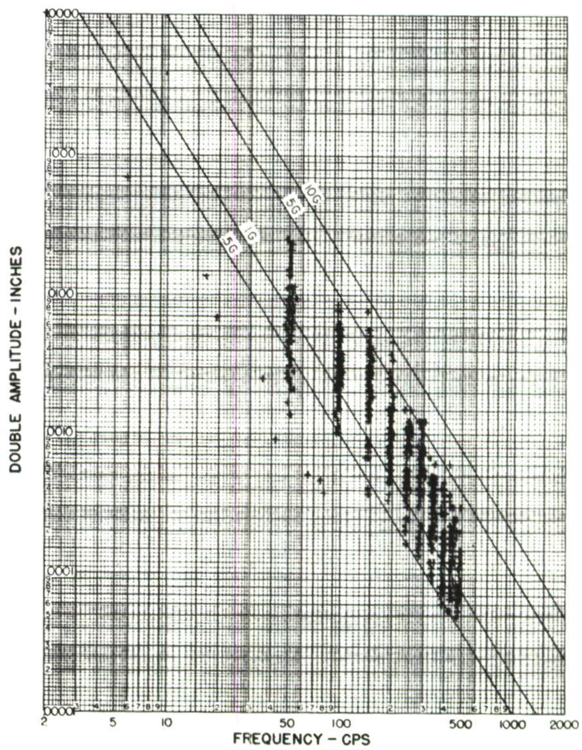


Figure 32. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE 95" ABOVE DECK, STA-630

Figures 29 to 32. Summary Plots for Individual Vibration Pickups

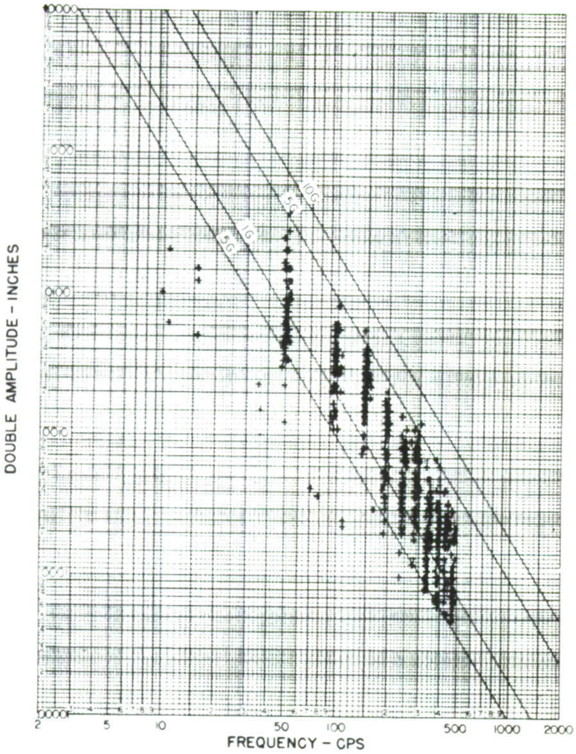


Figure 33. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE
115" ABOVE DECK,
STA-630

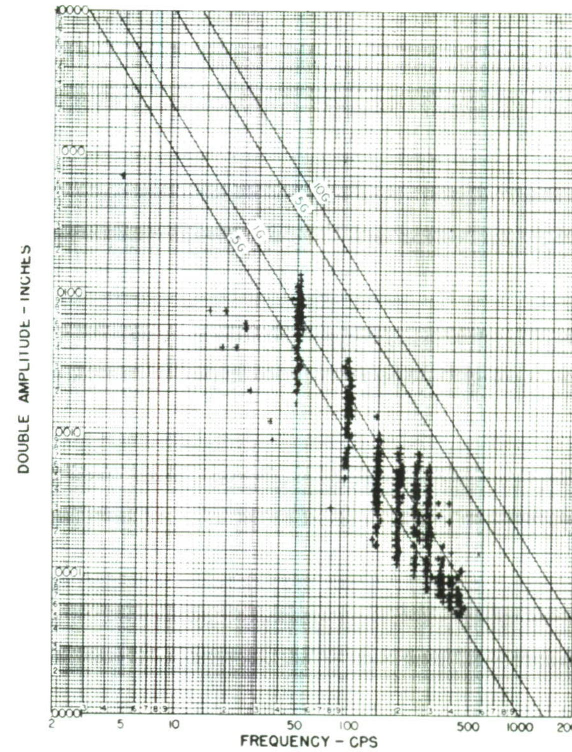


Figure 34. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE
57" ABOVE CARGO DECK,
STA-680

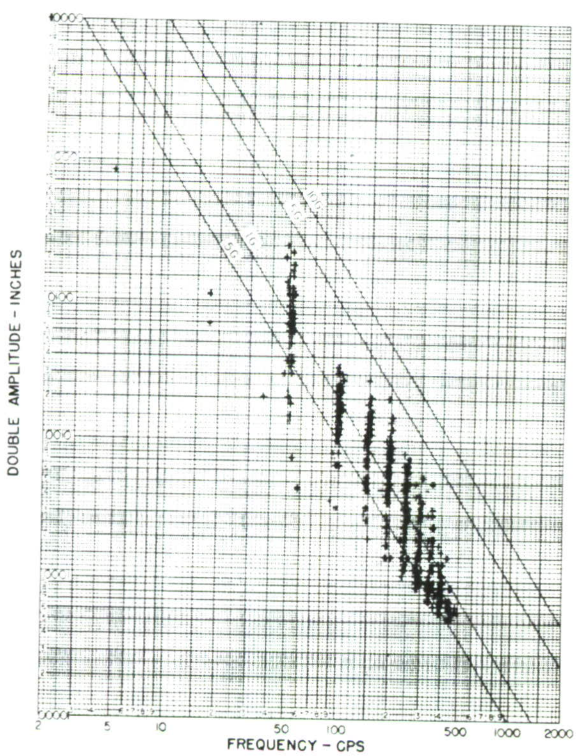


Figure 35. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE
95" ABOVE CARGO DECK,
STA-680

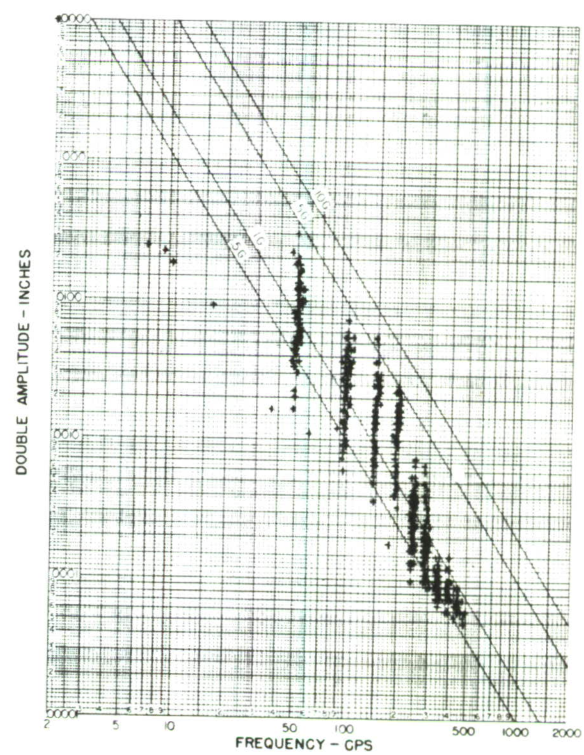


Figure 36. DIRECTION: LAT
LOCATION: LEFT SIDE OF FUSELAGE FWD. OF PROP PLANE
115" ABOVE CARGO DECK,
STA-680

Figures 33 to 36. Summary Plots for Individual Vibration Pickups